Low Cost Antennas for Direct Broadcast Satellite Radio

T.K. Wu and J. Huang
Jet Propulsion I Amatory
California Institute of q'ethnology
Pasadena, CA 91109

Abstract

Two omni-directional and circularly polarized low gain antennas (the crossed drooping dipole and the TM_{21} mode circular patch antenna) are developed for direct broadcast satellite radio (DBSR) outdoor mobile terminal applications. Two medium gain circularly polarized microstrip patch arrays (one uses the conventional circular polarization (CP) feed and the other uses the sequentially arranged CP feed techniques) arc also developed to provide at least 12 dBic peak gain for DBSR indoor fixed terminal applications. The sequentially arranged CP fed array has a better CP performance over a broader bandwidth than the conventionally fed array. All the antennas are small in size/mass and inexpensive in fabrication cost. The patch antennas have also the low profile feature.

Introduction

The Direct Broadcast Satellite Radio (DBSR) Program is a joint effort between NASA and the United States Information Agency/Voice of America (USIA/VOA). DBSR will offer audio signals via satellite with various levels of sound quality (AM, FM, and CD) to reach a variety of radio receiver types (fixed, portable, and mobile) in various environments (indoor/outdoor, rural, urban, and suburban). The mobile antenna requirements are: (1) small size and mass, (2) 2,05 GHz operating frequency with 40 MHz bandwidth, (3) right hand circular polarization (RHCP), (4) 360° azimuthal cove.rage, (5) at least 4 dBic peak gain between 40 and 60° from zenith. The mobile antennas arc to be mounted on an 18' diameter ground plane simulating the automobile's antenna mounting platform. The indoor fixed terminal medium gain antenna requirements arc the same as the mobile antenna except providing at least 12 dBic peak gain to account for the additional propagation loss through the building enclosure.

JPL has successfully conducted two reception experiments and demonstrations via a NASA Tracking Data Relay Satellite (TDRS) at 62° West longitude with sound signals sent from White Sands, New Mexico. These live demonstrations were conducted at Pasadena, California and at Buenos Aires, Argentina in June and September 1993, respectively. This paper describes the low cost antennas developed at JPL for the two demonstrations. They are drooping dipole and TM_{21} mode circular patch antennas for mobile platforms as well as medium gain microstrip antennas for indoor environments. They arc described individually in the following sections.

Drooping Dipoles

A crossed drooping dipole antenna was designed based on the previous mobile satellite MSAT antennas at L-band [1]. The crossed drooping dipole antenna has four arms curved downward with two shorter arms' length and two longer arms' length than quatcr-wavelength to provide better circular polarization, a movable tuning ring for better impedance matching and a finite and adjustable height ground plane for pattern shape adjustment. Figure 1 illustrates the physical configuration of this antenna. The impedance match tuning ring, dipole length (1.2" short arms' length and 1.8' long arms' length) and 3,2" height (measured from the ground plane to the center of the dipole arms) were all adjusted to achieve the optimum RF performance at

2.05 GHz. The 3.2" height was also found to direct the beam peak at ± 60°. Figure 2 shows a representative measured radiation pattern for onc of these drooping dipole antennas. The measured VSWR and gain performances of the antenna arc summarized in 'Table 1. They all meet the DBSR omni mobile antenna requirement stated earlier.

Omni Patch Antennas

The circular patch antenna, as illustrated in Figure 3, is modified from the MSAT TM_{21} mode patch antenna at 2,295 GHz [2]. The patch antenna's diameter is 6" with a 5.2" diameter top radiating patch, which is printed on a 0.5" thick Nomex honeycomb with 5 mil thick Micaply face sheets. The original MSAT patch antenna was measured with an external feed component consisting of a two-way power divider and two 90° hybrids. To reduce the feed circuit loss and to provide a precise amplitude and phase input at the four feed ports, a printed circuit board (PCB) stripline feed, as depicted in Figure 4, was designed and fabricated. 'I'his circular patch antenna has four specific feed points connected to the four output ports of the printed circuit board (PCB), which was designed to provide the correct amplitudes and phase quadratures (for right hand circular polarization or RHCP) at the four feed points. Thus the patch antenna was measured either with a PCB feed or an external feed. Indeed, the patch antenna with the PCB feed has approximately one dB higher gain and demonstrated the conformability of the whole antenna system. Table 1 summarizes the measured peak gain, its peak direction, and the VSWR of all the antennas. Figure 5 shows a representative measured radiation pattern for these antennas. Further, the size of this TM_{21} mode patch antenna may be reduced to 3.75" in diameter) by replacing the lower dielectric constant honeycomb with a 0.125" thick Teflon-Fiberglass substrate (2.17 dielectric constant).

Medium Gain Antennas

Two patch array antennas (2 by 2 elements, 8.5" by 8,5" in size and etched on a 0.126" thick dielectric substrate) were developed to provide at least 12 dBic peak gain (at broadside). Both arrays have four square patches fed with two orthogonal microstrip feed lines for CP. Onc array uscs a conventional feed [3,4], as illustrated in Figure 6, to generate circular polarization. The four square patches (1.84" in element size and

4" spacing) arc fed by microstrip transmission lines with identical orthogonal feeds. The overall antenna size is 8" by 8". The other array, as depicted in Figure 7, uses the sequentially arranged feed technique [5,6]. Here the four patch elements are spaced 3.166" apart and arc excited by four sets of feeds arranged physically in the 0°, 90°, 180°, and 270° configuration. With this approach, not only the four sets of feeds arc symmetrical, but the undesirable higher order modes from all patches arc cancelled. Hence better CP performance over a wider bandwidth is obtained. Note that the single, feed probe of the array is located off the center by 90° in phase. Thus the top two patches arc 180° out-of-phase from the bottom two patches. The overall size of this array is 8.5" by 8.5" including the printed microstrip transmission lines. Figure 8 illustrates a representative measured radiation pattern from this array. The measured array performances arc summarized in Table 2. Clearly, the sequentially fed array gives better VSWR bandwidth, axial ratio, and sidelobe level(-24 dB SLL) performance than the conventional feed array. Due to the smaller element spacing for the sequential feed array, the peak gain is slightly lower than the conventional feed array. Note that the antenna size may be further reduced to approximately 6" by 6" in size by replacing the feed lines with a PCB feed circuit board behind the radiating patch elements.

Conclusion

Two different low gain omni antennas (the drooping dipole and the TM_{21} mode circular patch antennas), and two medium gain patch antennas were developed for the successful DBSR demonstrations in Pasadena, California and Buenos Aires, Argentina. These low cost antennas can be used either indoors or outdoors to receive digital audio signals from the TDRSS satellite. The patch antennas are more conformal than the drooping dipole antennas. For the medium gain antenna, the sequentially arranged CP fed array has a better CP performance over a broader bandwidth than the conventionally fed array. Finally, these antennas have myriad applications in modern satellite or wireless communication systems, such as, MSAT, INMARSAT, IRIDIUM, Globalstar, Odyssey, Geostar, etc.

References:

1. K. Woo, et al, "Performance of a family of onmi and steered antennas for mobile satellite applications," Proc. IMSC, Ottawa, Canada, 1990, pp. 540-546.

2. J. Huang, “Circularly polarized conical patterns from circular microstrip antennas,” IEEE Trans, vol. AP-32, no.9, Sept. 1984, pp. 991-994.

3. M. Haneishi and Y. Suzuki, “Circular polarization and bandwidth,” “ in Handbook of Microstrip Antennas, Ed. by J.R. James and P.S. Hall, Chapter 4, p. 220, Peter Peregrinus Ltd., London, U. K., 1989.

4. R.E. Munson, "Microstrip Antennas,” in Antenna Engineering Handbook, 3rd Ed. by R.C. Johnson, p. 7-16, McGraw-Hill, New York, 1993.

5. J. Huang, “A technique for an array to generate circular polarization with linearly polarized elements,’’~}~z Trans., vol. AP-34, Sept. 1986, pp. 1113-1124.

6. 1“. Teshirogi, et al, "Wideband circularly polarized array antenna with sequential rotations and phase shifts of elements," Proc. Int. Symp. on Ant. and Propag., Japan, 1985, pp. 117-120.

Acknowledgement:

We’d like to thank Mr. C. Chavez for fabricating and testing of all the antennas, Mr. R. Thomas for assisting in the design of the drooping dipole, Mr. J. Cardone, C. Cruzan and his group members for the etching and fabrication of the patch antennas and the PCB feed, and Mr. G. Hickey for fabricating the Nomex honeycomb sandwich.

TABLE 1. Summary of Measured Omni Antenna Performances at 2.0S GHz

Antenna Type	VSWR	Beam Peak (degree)	Gain (dBic)
Drooping Dipole	1.12	60	4.8
Patch w/o PCB Feed	1.4	36	5.5
Patch with PCB Feed			

Table 2. Summary of Medium Gain Antenna Performance at 2.0S GHz

Array Type	Conventional Feed	Sequential Feed
Peak Gain (dBic)	13.7	12.0
VSWR	1.13	1.48
Bandwidth (MHz)	82	132
Beamwidth (Deg.)	38	46
Sidelobe Level (dB)	-13	-24
Axial Ratio (dB)	1.4	0.8

Figure 1. Photo of a crossed drooping dipole antenna on a ground plane.

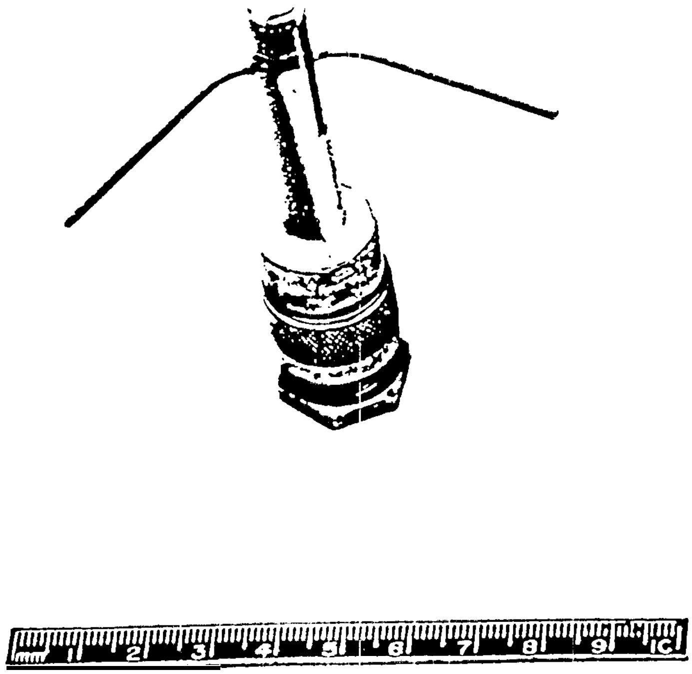


Figure 2. Measured drooping dipole antenna radiation patter ı a 2.05 GHz.

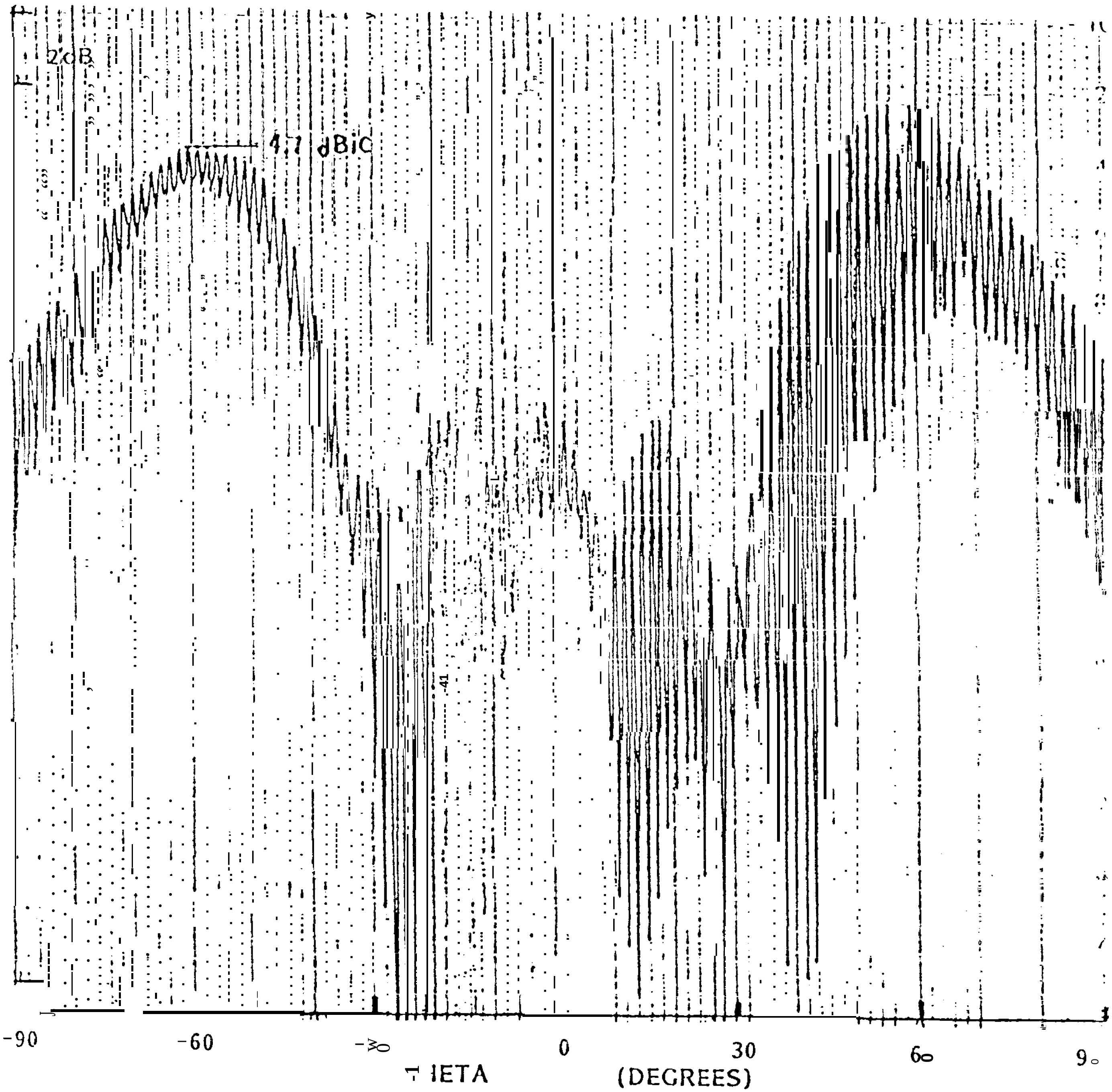
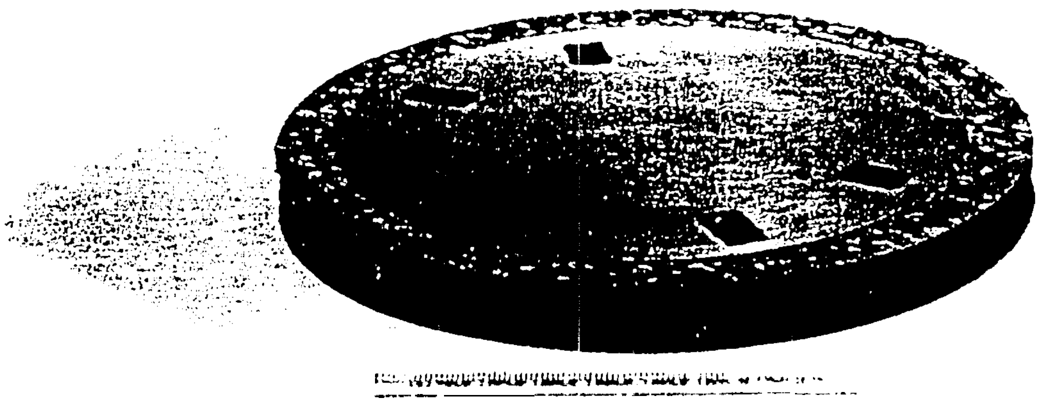


Figure 3. Photo of a TM_{21} mode microstrip antenna.



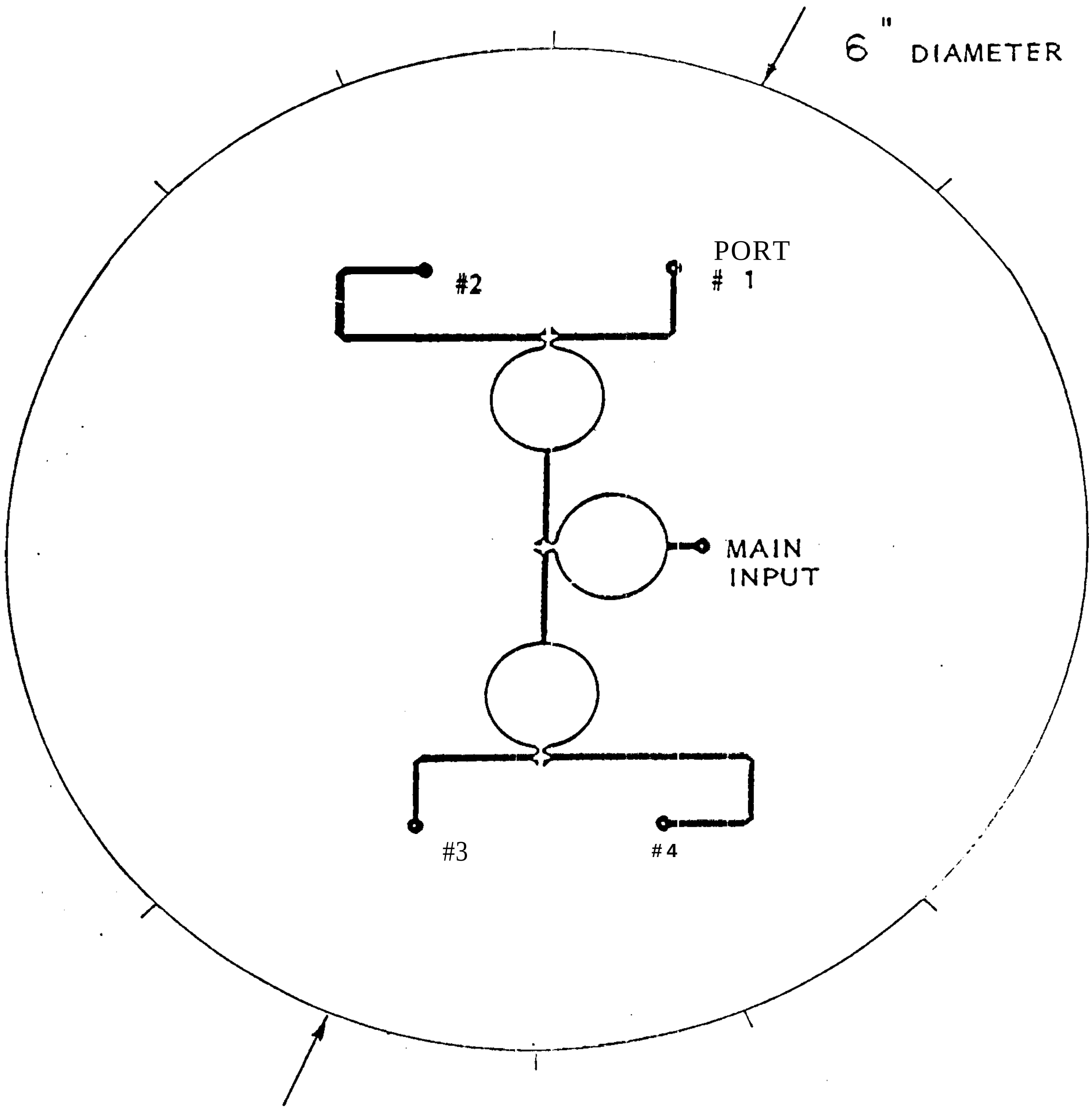
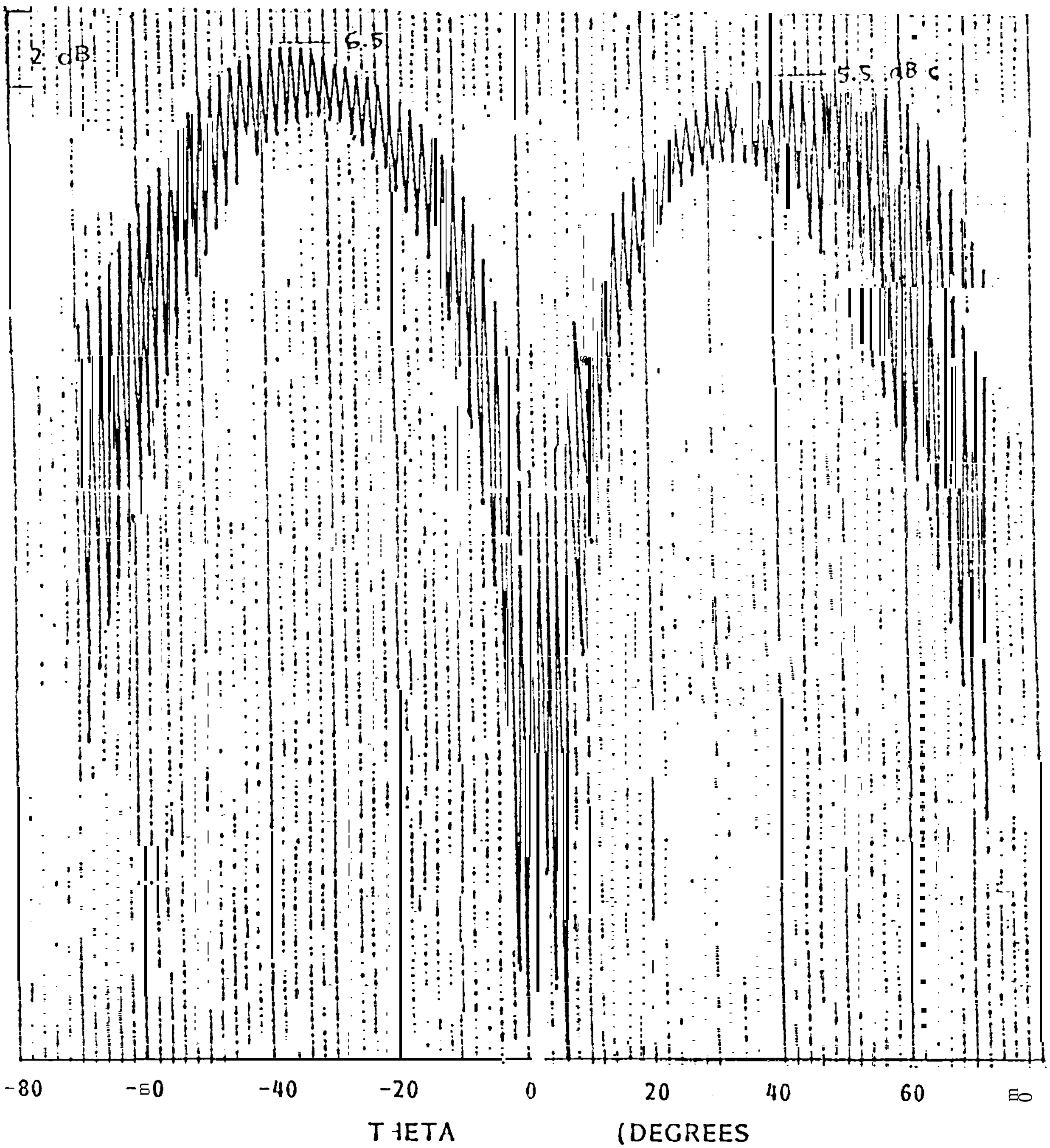


Figure 4. Strip-line printed circuit feed for the TM_{21} mode circular patch antenna.

Figure 5. Pattern of TM_{21} Mode Circular Patch Antenna (with PCB feed) at 2.05 GHz



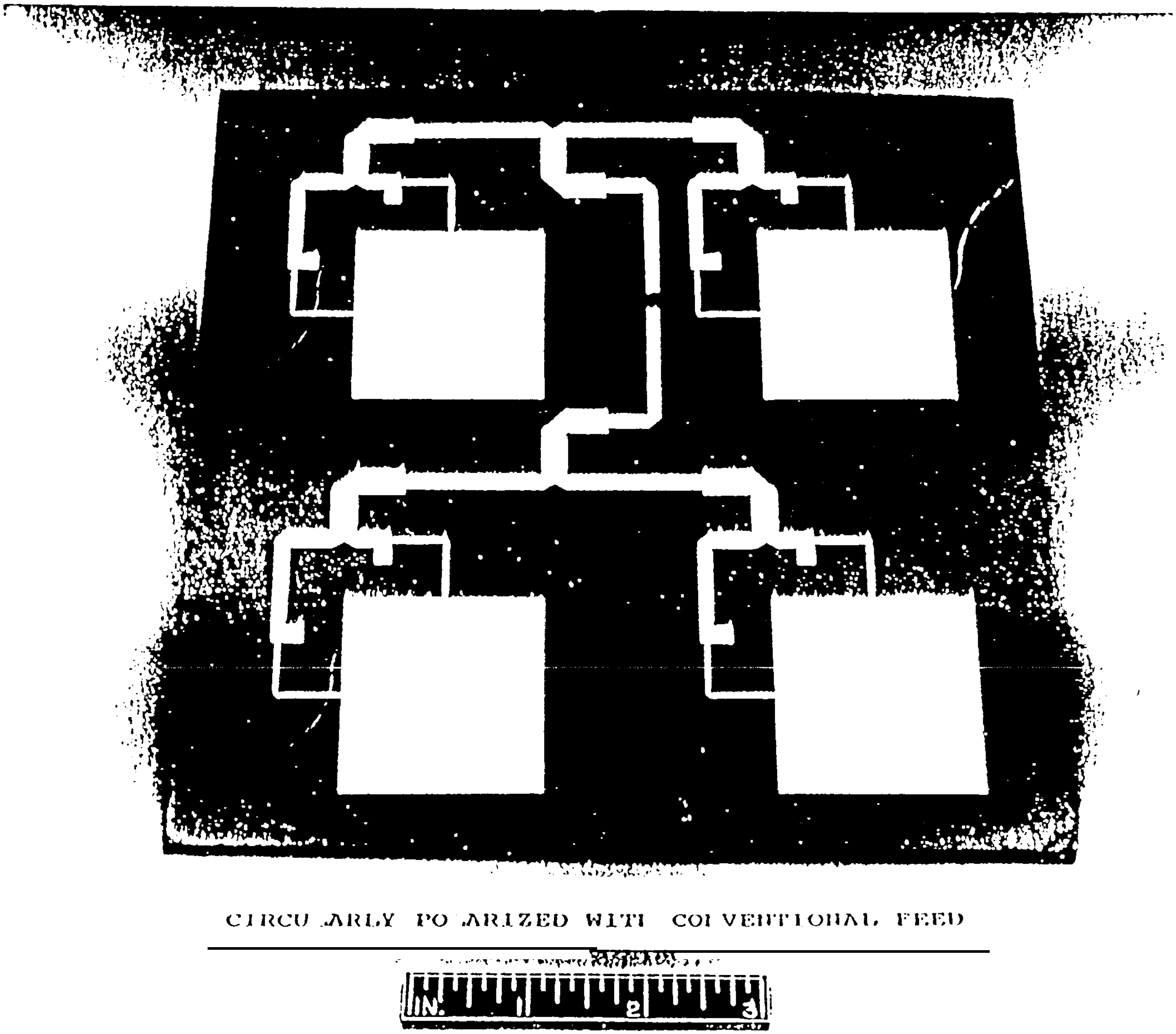
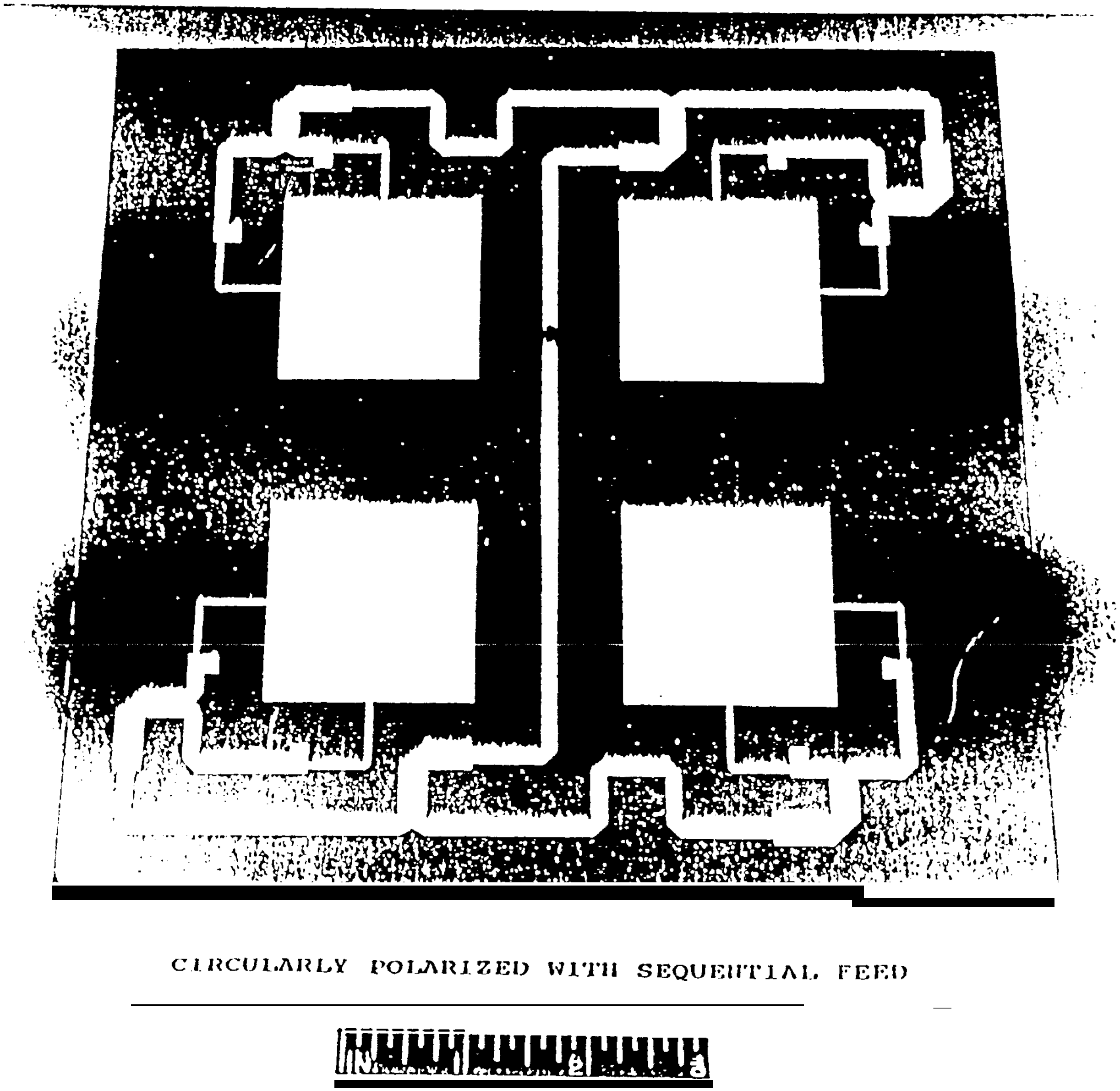


Figure 6. Circularly polarized microstrip array with conventional feed technique



CIRCULARLY POLARIZED WITH SEQUENTIAL FEED

Figure 7. Circularly polarized microstrip array with sequential feed technique